5

SUMMARY AND CONCLUSIONS

The development of the NII promises improved quality of life and increased productivity. Many human endeavors that are difficult or impossible now can be made easy and convenient by ubiquitous access to all forms of communication and information.

The subject of this report is the RII and whether these benefits can be realized in rural America. More particularly, we are concerned about the availability of telecommunication technologies that can be economically deployed in rural areas. Ideally, citizens living and working in rural areas should have the same access to information and telecommunication services that is available in urban areas.

The large distances between homes and towns, i.e., low population density, is the fundamental characteristic of rural areas. It is this characteristic that makes the deployment of telecommunication systems in rural areas more expensive. Often telecommunication equipment and facilities are designed for urban areas and are less than optimal for rural areas. For example, a typical rural system would be required to cover much larger distances but, at the same time, would need less information carrying capacity (Kotelly, 1995).

The higher deployment costs involved normally result in higher costs to the rural user. Possibly offsetting this, the large distances involved make telecommunication services more valuable in rural areas than in urban areas. When telecommunications makes a trip unnecessary, more fuel and time are saved. When communication takes place, a greater degree of isolation is reduced.

It should also be remembered that some rural areas are more remotely located than others. For this reason, most statements that can be made about rural telecommunications do not apply to every rural area. The majority of the rural population lives on farms and in small towns in farming areas. This is the environment that is assumed for the conclusions given in this section. However, special problems associated with other environments will be mentioned.

The approach taken in this study to analyze the availability of technologies for the RII began with the definition of a set of telecommunication services in Section 2. These services, restated below, represent major classes of telecommunication capabilities that already exist or are expected to become available in urban areas as the NII evolves:

- Two-way Voice
- Multiple-way Voice Teleconferencing
- Multiple-channel Audio Programming
- Low-speed Computer Networking
- Medium-speed Computer Networking
- High-speed Computer Networking
- Very High-speed Computer Networking
- Video Conferencing, Lossy
- Video Conferencing, Broadcast Quality
- Multiple-channel Video Programming
- Video on Demand
- Interactive Video.

Defining these telecommunication services makes it possible to talk about rural telecommunication needs and access to the NII in a technology-independent way. Thus, in Section 2 various rural information applications and the telecommunication services required by those applications are discussed. Then in Sections 3 and 4, important systems and technologies for the RII are discussed. Finally, in this section the availability of the defined telecommunication services in rural areas is examined based on the availability of systems and technologies to provide them.

Before this is done, it is important to take a brief look at other factors that will affect the implementation of the RII.

5.1 Factors Affecting the Implementation of the Rural Information Infrastructure

Major factors affecting the implementation of the RII include rural needs and applications, economics, and government regulations and policies.

5.1.1 Needs and Applications

The need for information spans all aspects of rural life, including health care, education, public safety, business, and recreation. Section 2 described rural information applications and how telecommunication services are used to support these applications. These applications are expected to improve the quality of life in rural areas. In addition, access to the NII is expected to contribute to the revitalization and diversification of the rural economy. Existing and new businesses dependent on the NII may find the lower real estate prices and lower taxes in rural areas attractive. However, these benefits must translate into an aggregate demand that is sufficient to support the high costs of the deployment of the RII. Massive government subsidies are not likely given the current efforts to decrease deficit spending.

5.1.2 Economics

In Sections 3 and 4, representative costs associated with the various technologies were provided. They provide information on the costs of implementing a particular technology (to be funded by the provider) and the costs of using the service (to be incurred by the user). This report has not considered the return on investment or cost-benefit analyses of the technologies. These analyses are needed before economically viable decisions can be made about a technology that might be implemented as part of the RII. Although not the focus of this study, some economic issues are pointed out in the analysis of the availability of services in rural areas given in Section 5.2.

5.1.3 Regulations and Policies

Regulations and policies affecting the RII are determined by Congress, the Administration, the Federal Communications Commission, state Public Utility Commissions, and county and local regulators. Most regulations are set with individual services in mind, dealing with such issues as standards, ownership, competitiveness, and rate structures. They are not usually intended to bring about a unified information infrastructure, that is, an infrastructure that provides all telecommunication services. Traditionally, policies have been developed to promote service cost controls and service competition for the consumer, or to ensure exclusive market rights to service providers. Policymakers have also provided special assistance to rural providers through REA (now RUS) loans and rate-averaging methods. Recently, NTIA's Telecommunications and Information Infrastructure Assistance Program (TIIAP) grants have provided assistance to many rural areas.

Historically, the telecommunication industry in America has been extensively regulated. A regulated monopoly model was initially used, but in the last 30 years, regulations have been relaxed somewhat. This process has left us with a telecommunication infrastructure which has been determined by a mix of regulatory and competitive forces. In the past decade we have seen competitive forces play a larger role as deregulation has accelerated. The impact of this trend can be seen in the restructuring that is taking place in the telecommunication industry. Continued deregulation will result in further changes in the U.S. telecommunication infrastructure. The purpose of this report is not to review telecommunication regulations and policies. However, it must be pointed out that the competitive forces at work on the information infrastructure may well result in different outcomes in rural areas than in urban areas. Competition should be promoted in general because of the many benefits it can confer on users, such as lower costs and more diverse service offerings. Where market forces fail, public policymakers should apply appropriate regulations to the resulting single provider.

Major telecommunication legislation is currently pending before Congress. The House and Senate have passed different versions of bills which would

- allow cable television companies to offer telephone service.
- allow telephone companies to offer cable television service.
- deregulate cable television rates.
- relax restrictions on radio and television station ownership.
- force local telephone companies to give competitors access to their networks.
- permit regional Bell telephone companies to offer long-distance service.

The final form of this legislation and its impact on the deployment of telecommunication technologies in rural areas cannot be determined at this time.

5.2 Ability of Technologies to Deliver Telecommunication Services

This report has emphasized the technologies that may support the RII. Table 5-1 indicates which technologies have the ability to provide telecommunication services now (indicated by a solid check) or could potentially provide them in the future (indicated by an open check). The table is somewhat subjective, but it is a best attempt to indicate what might reasonably be expected.

Table 5-1. Telecommunication Services That Can Be Delivered by Various Wireline and Wireless Technologies

Telecommunication Services	PSTN	Narrow-band ISDN	Broadband ISDN	Cable TV	Circuit-switched Networking	Packet-switched Networking	Fast packet, frame relay	Fast packet, cell relay	Land Mobile Radio	HF Radio	Terrestrial Broadcast TV	Terrestrial Broadcast Radio	MMDS	LMDS	Cellular Telephone	PCS	Wireless PBX	Rural and Subscriber Radio	BETRS	Paging	Packet Radio	Wireless LANs	Wireless Digital Modems	Fixed Satellite	Broadcasting Satellite	Mobile Satellite
Two-way Voice, Fixed	✔	✔	✓	✓	✔			✔	✔	✔				✓	✔	✓	✔	✔	✔			✓	✔	✔		✓
Two-way Voice, Mobile/Portable (M/P)				✓					✔	✔					✔	✓	✔					✓				✓
Multiple-way Voice Teleconferencing	✔	✔	✓	✓	✔			✔	✔					✓	✔	✓	✔	✔	✔			✓	✔			
Multiple-channel Audio Programming				✔						✔		✔		✓										✔	✓	
Low-speed Computer Networking, Fixed	✔	✔	✓	✓	✔	✔			✔	✔	✔	✔		✓	✔	✓		✔	✔	✔	✔	✔	✔	✔		✓
Low-speed Computer Networking, M/P				✓					✔	✔	✔	✔			✔	✓				✔	✔	✔				✓
Medium-speed Computer Networking		✔	✓	✓	✔		✔				✓			✓				✔			✓	✔	✔	✔		
High-speed Computer Networking			✓	✓	✔		✓	✔			✓			✓								✔	✔			
Very High-speed Computer Networking			✓		✔			✔																		
Video Conferencing, Lossy	✔	✔	✓	✓	✔			✔	✓					✓	✓	✓		✓	✓			✓	✔			✓
Video Conferencing, Broadcast Quality			✓	✓	✔			✔						✓									✔			
Video Programming, <150 channels				✔							✔		✔	✓										✔	✔	
Video Programming, >150 channels				✓									✓	✓												
Video on Demand			✓	✓									✓	✓												
Interactive Video			✓	✓									✓	✓												

✔ indicates current capability, ✓ indicates potential capability

5.2.1 Voice and Audio Telecommunication Services

Looking first at the Voice and Audio Telecommunication Services, it is clear that a number of technologies are available to provide these services. The most widely deployed technology is the telephone system (PSTN). There is currently no other wireline telephony system to provide competition to the PSTN in rural areas. The telecommunication legislation pending before Congress may allow cable TV systems to provide telephone service. It is highly unlikely, however, that cable TV systems would be extended to serve individual farms or isolated homes.

In some rural areas, wireless technologies such as cellular telephone may be able to provide competition to the PSTN. Cellular telephone coverage over the United States should be nearly complete by the year 2000. Only large wilderness areas of Alaska, the desert west, and possibly some parts of the central northern states will remain uncovered. The wilderness areas of Alaska are particularly difficult to serve because of the low population density. Other wireless technologies can provide not only mobile/portable service, but also fixed service into some of the more remote areas. In the most remote areas, only HF radio and satellite telephone technologies may be feasible. As with wireline systems, service providers may be reluctant to extend their wireless systems to farms or isolated homes, thus limiting choices for consumers who live in more remote locations.

5.2.2 Computer Telecommunication Services

Computer Telecommunication Services may be the heart of the NII. Many technologies are available to provide fixed and mobile/portable low-speed computer networking services. Dial-up modem access through the PSTN is most commonly used to provide fixed low-speed service today. So far, the demand for mobile/portable low-speed service has been slow in developing. Again, the most remote areas may only be covered by HF radio and satellite systems.

Medium-speed computer networking service can be provided through narrow-band ISDN and switched digital circuits. In principle, these technologies are or can be deployed in many rural areas. Only in the most remote areas would they not be feasible. In the future, cable TV systems may provide medium-speed service in towns and small towns. Again, service providers may be reluctant to extend their systems to farms or isolated homes.

High-speed and very high-speed computer networking services may be very difficult to deploy in rural areas. In the future, enhanced PSTN and cable TV systems may be able to provide high-speed service in towns and small towns. Outside of the towns, the cost of covering long distances with fiber optics or coaxial cable and technical difficulties with broadband radio systems limit what can be done without future technological development. In principle, high-speed and very high-speed computer networking services can be designed to effectively support voice, data, and video transmission. The provision of all telecommunication services through one infrastructure increases the value of that infrastructure. The degree to which this could be used to extend the reach of the RII into remote areas is not known.

5.2.3 Video Telecommunication Services

As can be seen in Table 5-1, very few technologies currently exist for providing video telecommunication services in rural areas. Switched digital circuits and narrow-band ISDN are currently available in many metropolitan areas, but are only available on a limited basis in rural areas. Video programming up to 150 channels is available from both cable TV and satellite broadcasting. More than 150 channels is expected to become available from cable TV in the future.

5.2.4 Today's Rural Information Infrastructure

Telephone companies and cable TV companies are currently the primary providers of telecommunication services in rural America. It is expected that this will continue to be the case as the RII develops. Each one is deploying or planning to deploy new equipment and systems.

Telephone service in rural America is provided by major telephone companies and independents, including cooperatives. Experience in rural areas indicates that the independent and cooperative telephone companies provide better service and have newer equipment, though typically at a higher price to consumers. This seems natural since the major telephone companies have large urban markets in which to invest their capital and receive the highest return. However, the independents and especially the cooperatives have only their limited service areas in which to invest and have closer ties to the community.

The Rural Utility Service (RUS) has mandated that each state prepare a State Telecommunication Modernization Plan. Without such a plan, telephone companies eligible to borrow for capital investment from the RUS are not able to. In the State of Oklahoma, for example, with 34 telephone companies, the plan requires all local loops to be 18,000 feet or less in length. Pioneer Telephone, the largest telephone cooperative in Oklahoma, has some local loops as long as 15 miles but is working toward having no loops longer than 18,000 feet. When their infrastructure improvements are completed, they will be able to offer T1 access anywhere in their service area. Pioneer may be a premier example of a telephone cooperative. They have 100% single line (no party line) service and digital switching. They offer switched 56 kbps service and plan to offer dial-up access to the Internet. Pioneer provides cellular telephone and paging services. They plan to run fiber optic circuits, providing 155 Mbps transmission speeds, to each school in their service area. This will allow the schools to participate in distance learning programs. Pioneer is an advocate of deregulation that would enable the schools to make up some of their costs by selling their excess fiber optic capacity in their communities.

The cable television industry's interest in providing a broad range of telecommunication services was detailed in Section 3.2. Already deployed or capable of being deployed in small towns, cable TV systems may soon be able to provide fixed telephone service, wireless telephone service, and computer networking services.

Thus, telephone and cable TV companies that have offered distinct services in rural areas and have survived economically may soon be competitors providing similar services. Each could make investments to provide services that take business away from the other. The degree to which rural markets can support duplicate investments to provide the same services is not known. The long-term effects on market viability of each service in rural areas is also not known. Care should be taken by regulators to watch the unfolding of events in rural areas as deregulation proceeds.

5.3 Conclusions

The following general conclusions can be drawn concerning the development of the RII:

- It is desirable to have access to telecommunication services in rural areas that approaches that available in urban areas.

- Distance and low population density are the distinctive features of rural areas affecting telecommunications. These factors increase the costs of providing telecommunication services. In addition, systems and technologies developed for urban areas may be less than optimal for rural areas.

- The distances involved in living in rural areas increase the benefit and therefore value of telecommunication services. Telecommunication enables applications such as distance learning that can alleviate or eliminate some rural disadvantages. Telecommunication can make rural areas more attractive for some businesses and result in revitalization of the rural economy.

- The effects of deregulation on rural areas are less certain than on urban areas and should be carefully watched by regulators. Rural areas may not be able to support several competitive service providers. Multiprovider markets should be developed wherever feasible in both urban and rural areas as a means to reduce costs and spur innovation. Where a given market fails and only a monopoly service provider exists, policymakers should prescribe appropriate regulations to protect the public interest.

- Historically, the deployment of telecommunication capabilities in rural areas has been delayed relative to deployment in urban areas. This has been due to the inability of rural areas to compete with urban areas for capital, since rural areas do not offer as high a return on investment. Telephone cooperatives have proven to be effective in accelerating the deployment of new technology. Telecommunication cooperatives could be an effective way of reaching rural areas with the NII.

- Government regulations and policies will play an essential role in the development of the RII. Different regulations and policies will likely be required in rural areas than in urban areas.

- The technical deployment of advanced telecommunication capabilities may not be very different in small towns than it is in urban areas. Reaching isolated homes and businesses in farming areas and especially remote desert and wilderness areas will be difficult, and will require technology deployments different from that in urban areas.

The following conclusions can be drawn concerning the assessment of technologies to support the RII:

- Numerous technologies can support all of the voice and audio telecommunication services. In many cases, those technologies are available to rural consumers today and competition by various providers may be viable.

- Numerous technologies are available in rural areas to provide low-speed computer networking service, such as dial-up access to computer networks via the PSTN. As demand increases for faster transmission speeds, current implementations of technologies will prove inadequate to meet that demand.

- High-speed and very-high speed computer networking services could effectively support the transmission of voice, data, and video information. Theoretically, a single infrastructure could be used to extend the NII into rural areas. Technical, regulatory, and economic barriers, however, may render this impractical.

- No technologies presently support all of the video telecommunication services. Video programming is provided in rural areas by terrestrial broadcasting, cable TV, and satellite broadcasting. In more remote regions, however, only satellite broadcasting provides video programming on a par with that available in urban areas. Video conferencing can be provided over switched digital circuits or narrow-band ISDN and is available in some rural areas. Video on demand and interactive video are planned but will be provided by select technologies that probably cannot economically reach farms, ranches, and isolated homes.

- It is likely that new technology will need to be developed to economically deliver advanced computer networking and video services to individual farms, ranches, and isolated homes. A wireless technology will most likely be required, and certainly the most remote users can only be reached by wireless technology.

6
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APPENDIX A

ACRONYMS AND ABBREVIATIONS

ACSB	amplitude companded single-sideband
AM	amplitude modulation
AMPS	Advanced Mobile Phone Service
AMSC	American Mobile Satellite Corporation
AMSS	aeronautical mobile-satellite service
ATC	air traffic control
ATIS	automated terminal information service
ATM	asynchronous transfer mode
ATV	advanced television
BETRS	Basic Exchange Telecommunications Radio Service
BOC	Bell Operating Company
bps	bits per second
BRI	basic rate interface
BSS	broadcasting-satellite service
BTA	Basic Trading Area
CATV	Community Antenna Television
CB	citizen band
CCS	hundred call seconds per hour
CD	compact disc
CDMA	code-division multiple access
CDPD	Cellular Digital Packet Data
CMRS	Commercial Mobile Radio Service
CO	central office
COMSAT	Communications Satellite Corporation
CTIA	Cellular Telecommunications Industry Association
DAB	digital audio broadcast
DBS	direct broadcast satellite
DECT	Digital European Cordless Telephone
DSP	digital signal processing
DTH	direct-to-home
DTS	Digital Termination Services
EO	end office
ESMR	Enhanced Specialized Mobile Radio
FCC	Federal Communications Commission
FDDI	fiber distributed data interface
FDM	frequency-division multiplexing
FDMA	frequency-division multiple access
FM	frequency modulation
FM HSS	FM high-speed subcarrier
FN	Fiber Node

FSK	frequency-shift keying
FSS	fixed-satellite service
FTTC	Fiber to the Curb
GSO	geostationary orbit
HDTV	high-definition television
HEO	highly-elliptical orbit
HF	high frequency
HFC	Hybrid Fiber/Coax
HSDS	High Speed Data Services
hz	hertz
IMTS	Improved Mobile Telephone Service
IR	infrared
ISDN	Integrated Services Digital Network
ISM	industrial, scientific, and medical
ITFS	Instructional Television Fixed Service
ITS	Institute for Telecommunication Sciences
ITU	International Telecommunication Union
IXC	interexchange carrier
JTC	Joint Technical Committee on Wireless Access
kbps	kilobits per second
kHz	kilohertz
LAN	local area network
LATA	local access and transport area
LEC	local exchange carrier
LEO	low-Earth orbit
LMDS	local multipoint distribution service
LMR	land mobile radio
LMSS	land mobile-satellite service
LPA	log-periodic antenna
Mbps	megabits per second
MDS	multipoint distribution service
MEO	medium-Earth orbit
MHz	megahertz
MMDS	Multichannel Multipoint Distribution Service
MMSS	maritime mobile-satellite service
MPEG	Motion Pictures Experts Group
MSA	Metropolitan Statistical Area
MSS	mobile-satellite service
MTA	Major Trading Area
MTSO	mobile telephone switching office
NII	National Information Infrastructure
NTIA	National Telecommunications and Information Administration
NTSC	National Television Systems Committee
OFS	Operational Fixed Service
OMB	Office of Management and Budget
OPASTCO	Organization for the Protection and Advancement of Small Telephone Companies

PBX	private branch exchange
PCM	pulse-code modulation
PCS	personal communications services
PDA	personal digital assistant
PID	Premises Interface Device
PN	pseudorandom noise
POCSAG	Post Office Code Standard Advisory Group
POP	point of presence
POTS	plain old telephone service
PRI	primary rate interface
PSTN	public switched telephone network
RAD	Remote Antenna Device
RASP	Remote Antenna Signal Processing
RBDS	Radio Broadcast Data System
REA	Rural Electrification Administration (now called the RUS)
RFID	radio frequency identification
RII	Rural Information Infrastructure
RSA	Rural Service Area
RSMS	Radio Spectrum Measurement System
RUS	Rural Utilities Service
SMDS	switched multimegabit data service
SMR	Specialized Mobile Radio
SNG	satellite news gathering
SONET	synchronous optical network
TACAN	Tactical Air Navigation
TCI	Tele-Communications, Inc.
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	time-division multiplexing
TDMA	time-division multiple access
TIA	Telecommunications Industry Association
TIIAP	Telecommunications and Information Infrastructure Assistance Program
TIROS	Television and Infrared Observation Satellite
TVRO	television receive-only
VHF	very high frequency
VOR	Very High Frequency Omnidirectional Range
VTS	Video Telephony Services
WDM	wireless digital modem
WPBX	wireless private branch exchange

APPENDIX B

EXAMPLE OF RURAL SPECTRUM USAGE

This appendix describes measurements of rural spectrum usage in the 108-MHz to 19.7-GHz frequency range. The measurements were conducted at Eureka, California, using the NTIA/ITS Radio Spectrum Measurement System (RSMS).

The RSMS is a mobile, self-contained, computer-controlled radio receiving system capable of many measurement scenarios over a frequency range of 30 MHz to 22 GHz. Detailed information on the RSMS software, hardware (vehicle, instrumentation, antennas, and receiver front-end), calibration procedures, and other measurement capabilities are provided in Sanders and Lawrence (1995).

B.1 Survey Site Selection

Historically, most RSMS broadband spectrum surveys have been performed in urban areas where spectrum usage was expected to be relatively high. For the purposes of this project, however, spectrum usage patterns in rural areas were assessed. A rural coastal location was chosen for the survey so that both land and marine radio usage patterns would be included. Therefore, Eureka, located in the Northwestern corner of California, was selected.

B.2 Spectrum Survey Measurements

Two decades of making such measurements in cities across the United States suggest that general patterns of spectrum occupancy tend to be repeated from site to site. Emissions from the following sources are commonly observed during RSMS spectrum surveys:

- land-mobile, marine-mobile, and air-mobile communication radios;
- terrestrial, marine and airborne radars, and airborne radio altimeters;
- radionavigation emitters, such as Tactical Air Navigation (TACAN) and Very High Frequency Omnidirectional Range (VOR);
- cellular and trunked communication systems;
- broadcasting transmitters such as UHF and VHF television, and Multichannel Multipoint Distribution Systems (MMDS);

- industrial, scientific and medical (ISM) sources, vehicular tracking systems, welders, and microwave ovens; and

- common carrier (point-to-point) microwave signals.

Emissions that normally cannot be received during spectrum surveys are:

- satellite uplink and downlink emissions;

- astronomical emissions;

- some types of spread spectrum signals; and

- radio transmitters that are turned off.

Although the last category is self-evident, questions exist regarding the extent to which users who have frequency assignments either do not operate, or operate very rarely, with those assignments. Appendix C in Sanders and Lawrence (1995) discusses this and related problems more fully.

Each radio band is measured with a hardware configuration and measurement algorithm specifically selected to give the most useful description of the particular type of signal(s) expected in that band. The measurement system parameters specially configured for each signal type include: antennas, signal conditioning, tuning speed, measurement bandwidth, detector mode, and measurement repetitions. The measurement control software automatically switches the measurement system to the proper configuration for each survey band. (The spectrum measured by the RSMS is divided into selected frequency ranges called survey bands.) The measurements are repeated in various survey bands according to specifications established by consideration of signal intercept probability, signal variability, measurement significance, and expenditure of system resources.

B.2.1 Survey Band Events

RSMS survey measurements are conducted in an automatic mode, with the RSMS configured as two measurement systems, identified as "System-1" for frequency measurements below 1 GHz, and "System-2" for simultaneous measurements above 1 GHz. Software provides instructions to configure each receiver system, execute measurement routines, record measured data, and maintain a real-time log of the measurements and key parameters. Unattended operation of the measurement system is made possible through this use of computer control.

As stated earlier, the spectrum measured by the RSMS is divided into selected frequency ranges called survey bands. Each survey band is measured according to a computer-stored list of measurement parameters and instrument settings called a band event. Each band event combines one of the measurement algorithms with a particular set of signal input ports, receiver front-end configurations, spectrum analyzer modes and settings, and data recording options. Band event parameters for System-1 and System-2 are described more fully in Sanders and Lawrence (1995).

B.2.2 Band Event Schedules

Using software control, any band event can be executed by an operator at any time. For spectrum surveys, many band events are used to span several gigahertz of spectrum and each event requires a different amount of time to execute. Measurement software also includes an automated band event execution mode where any of the band events may be programmed (scheduled) to execute in any sequence for any amount of time (within hardware limits on continuous operation of the measurement system).

Band event priority is an important consideration when scheduling standard band events; some frequency bands in a spectrum survey are of more interest to spectrum managers than others. Highly dynamic bands (where occupancy changes rapidly) include those used by mobile radios (land, marine, and airborne) and airborne radars. These bands are measured often during a spectrum survey in order to maximize opportunities for signal interception. Bands that are not very dynamic in their occupancy (such as those occupied by commercial radio and television signals or fixed emitters such as air traffic control radars) need not be observed as often, because the same basic occupancy picture will be generated every time. Such bands are given a low priority and less measurement time. An extreme case is that of the common carrier bands, where spectrum usage in a given location essentially does not change. Generally, these are only measured once during a survey and are not included in the band event schedules.

B.3 Spectrum Survey for Eureka, California

The rural spectrum survey was conducted for approximately one week, using the RSMS in an automatic measurement mode. The measurement system was preprogrammed to continuously run software algorithms tailored to the characteristics of the radio emitters in individual frequency bands. The RSMS was parked at the Redwood Fairgrounds in Eureka, a location that was relatively high compared to the rest of the town and provided good radio coverage of the rest of the community. The site was reasonably removed from powerful RF transmitters, but some random noise was expected from passing vehicular traffic.

The measurement algorithms used for RSMS spectrum surveys are called swept, swept/m3, stepped, and azimuth-scan. Swept measurements consist of repetitive sweeps across a frequency band. Swept/m3 measurements consist of repetitive sweeps across a band, with maximum, minimum, and mean activity levels being returned at the end of the measurement period. Stepped measurements are made by tuning the measurement system to a single frequency for a period of time, making an amplitude measurement at that frequency, then switching to another frequency, making an amplitude measurement, and so on until an entire band has been measured. Azimuth-scans are performed by slowly rotating a dish antenna around the horizon, while rapidly sweeping a frequency band in maximum-hold mode. All of these algorithms are described in detail in Sanders and Lawrence (1995).

The band event schedules used for the Eureka measurements were identical to those described in Sanders and Lawrence (1995). The sequenced schedule was prepared so that all events would be run within an eight hour period such that, after a few days of 24-hr data collection, certain bands would be measured at least once during each hour. Because of unrelated demands on RSMS availability for measurements, this sequence could not be completed for Eureka and, consequently, time-of-day data analysis was not performed.

The band event tables in Sanders and Lawrence (1995) show the measurement system parameters used for each survey band. Explanations of the measurement algorithm selections are also found in Sanders and Lawrence (1995). All survey bands for System-1 were measured with a 0.1-1.0 GHz log-periodic antenna (LPA) mounted at a 45° angle (for slant polarization) and aimed toward the main part of town. The System-2 survey bands (except for azimuth-scanning bands[1]) were measured with a 0.5-18 GHz slant polarized biconical omnidirectional antenna. For the azimuth-scanning survey bands a rotating 1-meter parabolic (dual horizontal/vertical feed) antenna was used.

All of the measured data, except the azimuth scanning measurements previously mentioned, underwent an additional cumulative processing step before being displayed. Every frequency data point recorded for swept/m3 measurements was cumulated such that the graphed data points show the maximum of maximum received signal levels (RSLs), mean of mean RSLs, and minimum of minimum RSLs (see Sanders and Lawrence, 1995) for a discussion of swept/m3 cumulative processing). Cumulative processing of stepped and swept measurements results in graphs showing maximum, mean, and minimum RSLs of all scans. On all graphs of cumulated data, maximum and minimum curves are drawn with solid lines and mean curves with dashed lines.

B.3.1 Measured Data

Each survey band of measured data is graphically displayed on a single page along with corresponding frequency allocations and assignment information (Figures B-1 through B-39). Each survey band page shares an identical format. The principal band event parameters (e.g., IF bandwidth and measurement algorithm) and measurement location are included in the figure caption. The survey band graphs in the middle of the page show frequency in MHz on the x-axis vs. received signal level marked at 5-dBm increments on the y-axis.

The text above each graph (delimited by horizontal and vertical lines) shows the applicable U.S. Government and non-Government frequency allocations and corresponding typical user information (general utilization) for the survey band. The vertical lines delimit, by frequency, both the allocations and the measured survey band graph on the same page.

The frequency allocations (services) are entered according to convention just as they appear in the U.S. Government Table of Frequency Allocations (NTIA, 1993). These frequency allocations are listed such that primary services are printed in capital letters, secondary services are printed in normal upper and lower case, and allocations limited to specific functions are shown by following the service listing by a function in parenthesis.

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[1] The azimuth-scanning measurement routine is a special operator-interactive technique using a rotating dish antenna with the swept measurement algorithm. See Sanders and Lawrence (1995) for more about scanning.

The vertical lines are placed according to frequency separations in the allocation tables. The frequencies are written at the lower end of the vertical lines and are always in MHz. Any service entry that does not fit within the line-delimited space above the graph is given a number referencing the complete allocation text below the graph on the same page. If there is additional information pertinent to a specific U.S. Government or non-Government allocation it is indicated by a number referencing a note below the graph. General utilization, i.e., typical assignment usage notes for the U.S. Government or non-Government allocations that fall between the same vertical line delimiters also get a reference number if insufficient space is available. All notes are written in simple text format distinguishable from the allocated service entries that are entered according to convention as explained above.

B.3.2 Band-by-Band Observations on Spectrum Usage

A synopsis of the types of signals observed for each survey band in Eureka and the associated figure number is given in Table B-1. While not analyzed here, the spectrum usage in this rural area can be compared to that in a large U.S. city. Sanders and Lawrence (1995) provides a good example of spectrum usage in a large city for this comparison.

B.4 References

NTIA (1993), Manual of regulations and procedures for Federal radio frequency management, Part 4.1.3, U.S. Department of Commerce, National Telecommunications and Information Administration, Washington, D.C., May.

Sanders, F. H. and V.S. Lawrence (1995), Broadband radio spectrum survey at Denver, Colorado, NTIA Report 95-321, 100 pp., in press.

Table B-1. Comments on the Eureka Spectrum Usage Measurements

Survey Band	Figure	Comments
108-162 MHz	B-1	Between 108 and 118 MHz, some VOR aeronautical navigation beacons appear to be transmitting continuously. These beacons appear on the occupancy scans as vertical lines coming up from the minimum curve. Also, in the air traffic control (ATC) band (up to 136 MHz) ATIS (automated terminal information service) transmissions appear to be on most or all of the time. Frequently used ATC frequencies also appear as high points on the mean curve; ATC frequencies that were observed one or more times during the survey appear on the maximum curve. The Television and Infrared Observation Satellite (TIROS) signals that typically are found in the 137-138 MHz band normally cannot be received by the RSMS. A variety of mobile signals were observed in the 138-162 MHz portion of the spectrum. The signals between 138 and 156 MHz, are mobile and amateur signals. The signals between 156 and 162 MHz, are land mobile and marine mobile signals.*
162-174 MHz	B-2	A variety of fixed and mobile transmitters were observed in this band. The large signals on the mean signal curve near 162.5 MHz are public broadcast weather information frequencies. Some man-made noise, as from vehicular ignition systems, also occurs.
174-216 MHz	B-3	Television broadcast channel 13 (210-216 MHz) is readily apparent here. Some man-made noise, as from vehicular ignition systems, also occurs.
216-225 MHz	B-4	Very few signals were seen in this band. Most of the maximum curve is locally generated noise, as from vehicular traffic.
225-400 MHz	B-5	Very few signals were seen in this band. Most of the maximum curve is locally generated noise, as from vehicular traffic.
400-406 MHz	B-6	The maximum curve shows occupancy by a few signals above 402.5 MHz Otherwise, few signals were seen in this band, and only one that affected the mean curve (just above 403 MHz). The maximum curve is mostly locally generated noise.
406-420 MHz	B-7	Only four or five signals were seen in this band. The maximum curve is mostly locally generated noise.
420-450 MHz	B-8	No signals were seen in this band; the maximum curve is slightly elevated due to locally generated noise.
450-470 MHz	B-9	A relatively large number of mobile signals were observed in this band, as compared to the preceding bands. Some man-made noise also occurs.

* In Figure B-1, the measurement system noise level between 108-114 MHz is approximately 10 dB higher than in the rest of the graph. This is due to the insertion of 10 dB of front-end attenuation for measurements in this part of the spectrum. The attenuation had to be inserted to eliminate front-end intermodulation in the RSMS due to the presence of strong adjacent-band signals in the 88-108 MHz commercial FM broadcast band. Inserting the attenuation reduced measurement sensitivity by 10 dB. The signals that occur in this part of the band are VOR navigation beacon signals. Although the attenuation could have eliminated low-amplitude VOR signals from receivability, note that two or three VOR beacons are still apparent in the data below 114 MHz.

Table B-1. Comments on the Eureka Spectrum Usage Measurements (Continued)

Survey Band	Figure	Comments
470-512 MHz	B-10	No signals were seen between 470-506 MHz. Between 506-512 MHz, television broadcast channel 20 video and audio carriers were observed. Some man-made noise also occurs.
512-806 MHz	B-11	Three television channels were observed.
806-902 MHz	B-12	Many cellular mobile and cellular base station signals were observed. Note that the cellular base station-to-mobile channels show heavy usage. Some trunked signals were also observed.
902-928 MHz	B-13 & B-14	This band was measured with two different algorithms: swept/m3 and stepped. In this ISM band, only a few signals were observed. They are at 904.3 MHz, 905.6 MHz, and 925.5 MHz. Otherwise, little or no activity was seen.
928-960 MHz	B-15	A variety of mobile and fixed signals, many of them producing large mean responses, were observed.
960-1215 MHz	B-16	This band shows activity from airborne transponder beacons at 1090 MHz. Other signals seen were low duty-cycle, and are probably associated with beacon emissions. No TACAN signals were observed, inferred from the fact that no features appear in the minimum and average curves.
1215-1400 MHz	B-17	A variety of long-range radar signals were seen in this band. A local air route surveillance radar at 1280 MHz is continuously present. The other radars are transient, and are carried on vessels. Note the radar at 1350-1370 MHz that operates across 20 MHz of spectrum.
1350-1400 MHz	B-18	Approximately nine fixed and mobile signals were observed in this part of the spectrum.
1400-1530 MHz	B-19	Radar spurious emissions were seen up to about 1445 MHz. Above that frequency, a few mobile signals were seen.
1530-1710 MHz	B-20	A few impulsive signals were observed. The RSMS is not capable of measuring satellite sources, so these signals are terrestrial or airborne.
1710-2300 MHz	B-21	This band was measured with the azimuth scan technique, and signals from a number of point-to-point microwave links were observed. The measurement system noise floor changes across this scan, improving at higher frequencies. All of the observed links are analog.**
2300-2500 MHz	B-22	Signals from microwave ovens and other ISM devices were seen in this band, centered at about 2460 MHz.
2500-2700 MHz	B-23	This azimuth scan shows a few MMDS television signals between 2500-2515 MHz.
2700-2900 MHz	B-24	This band, commonly occupied by air traffic control and weather radars, shows occupancy by only a single air search radar at 2890 MHz.

** In Figures B-21, B-27, and B-33, sharp stair-step changes occur in the measurement system noise floor at 2, 4, and 8 GHz. These represent changes in measurement system noise figure at band edges, and are completely normal for an octave-band preselector such as that used by the RSMS for these measurements.

Table B-1. Comments on the Eureka Spectrum Usage Measurements (Continued)

Survey Band	Figure	Comments
2900-3100 MHz	B-25	This band, commonly used by tactical radars, shows occupancy by three, barely observable radars.
3100-3700 MHz	B-26	In this band, commonly used by tactical radars, four low-amplitude radar signals were observed around 3160, 3310, 3415, and 3570 MHz.
3700-4200 MHz	B-27	A single digital point-to-point microwave signal was observed (barely) at 4080 MHz.**
4200-4400 MHz	B-28	RSMS surveys can detect airborne radio altimeter signals in this band if aircraft flight patterns carry aircraft over the RSMS measurement van. However, in Eureka this was not the case, and no signals were received in this band during the survey.
4400-5000 MHz	B-29	A few signals were received in this band between 4400 and 4500 MHz. They appear to be analog signals and are probably from point-to-point microwave systems.
5000-5250 MHz	B-30	No signals were received in this band during the RSMS Eureka spectrum survey.
5250-5925 MHz	B-31	Although this band is commonly used by long-range weather radars, no signals were observed in this band during the RSMS Eureka survey.
5925-7125 MHz	B-32	Three analog terrestrial point-to-point microwave signals were observed in this band.
7125-8500 MHz	B-33	No signals were observed in this part of the spectrum at Eureka.**
8500-10550 MHz	B-34	The signals observed in this band at 9400 MHz are from short-range search radars.
10550-13250 MHz	B-35	No signals were observed in this part of the spectrum at Eureka.
13250-14200 MHz	B-36	No signals were observed in this part of the spectrum at Eureka.
14200-15700 MHz	B-37	No signals were observed in this part of the spectrum at Eureka.
15700-17700 MHz	B-38	No signals were observed in this part of the spectrum at Eureka.
17700-19700 MHz	B-39	No signals were observed in this part of the spectrum at Eureka.